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TRANSPLANTING SUGAR BEETS IN UTAH AND IDAHO

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INTRODUCTION

The transplanting of seed-bed-grown sugar-beet plants as a method of crop production to avoid some of the labor incident to growing the crop from field-sown seed and to obtain the advantages from the larger transplants has received scattering attention for more than a century. It is the historic method originally proposed by Achard,[1] used in a very small way in France, and later tried in some of the other beet-growing sections of continental Europe. This method did not persist as the sugar-beet industry increased in acreage, owing to serious obstacles met with in properly and economically performing the transplanting by hand. Interest in this problem abroad has again been recently revived, and especially so with the development of American transplanting machinery.[2]

The present method of growing sugar beets consists of planting a relatively large quantity of seed and later thinning the plants to an approximate stand of one plant to 12 inches of row. This is both expensive of seed and effort, as it requires much careful labor to remove the surplus plants while they are small. Further, the problem of increasing the acre yield of beets of satisfactory quality is now receiving a great deal of attention. Although adoption of improved practices has produced considerable improvement in yields for certain areas in this country, an insistent demand continues for economy of production and for the development of practices that will make still larger yields possible.

[1] ACHARD, F. C. ANLEITUNG ZUR ANBAU DER ZUR ZUCKERFABRIKATION ANWENDBAREN RUNKELRÜBEN UND ZUR VORTHEILHAFTEN GEWINNUNG DES ZUCKERS AUS DENSELBEN. Klassiker der Exakten Wissenschaften no. 159, p. 14–36. (Edited by E. O. Von Lippmann.) 1907.
[2] BIELMANN, O. RÜBENPFLANZMASCHINE. Centbl. Zuckerindus. 37: 727. 1929.

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The method of transplanting beets by machine merits consideration in the areas where yields have not been satisfactory because of shortness of season or because of disease epidemics as well as in areas having an inadequate labor supply. There would perhaps be little incentive to revive interest in transplanting sugar beets were one to depend upon hand labor to set out the plants. However, in the last few years a number of promising developments in plant-setting machines for use with truck crops have taken place, and it seems that with certain modifications some of these machines may be usable for setting out sugar-beet plants.

Prior to the beginning of these experiments, some work had been done in the United States on the growing of sugar-beet plants under protective covering and later transplanting them by hand into well-prepared fields. The recorded instances of those tests [3] deal only with the hand method of transplanting. Those tests gave results unfavorable to transplanting as a method of commercial beet growing. Several of the sugar-beet companies and beet growers have set beet plants by hand to fill in missing places in the stand in commercial fields, but this practice has not been found profitable.

The work here reported was conducted in Utah and Idaho from 1925 to 1929 to test the feasibility of using machine transplanters as a field practice in setting sugar beets. It has been productive of promising results, as shown by the results of several years of tests, which are brought together in summary form in this circular as a progress report on transplanting. It is hoped that these preliminary findings will encourage others to take up the development of this practice, which offers the possibility of increasing the yields of sugar beets and which offers advantages in meeting certain climatic and disease hazards.

EXPERIMENTAL WORK

Fields typical of the Utah-Idaho areas were selected for the experiments in transplanting sugar beets. Care was taken to utilize fertile fields which were of good tilth and of proper soil type. These had available an early irrigation water supply, and proper crop rotation and good farming had previously been practiced. The seed-bed preparation was the same as that recommended for commercial beet growing under ordinary methods. The experiments were carried on for four seasons, and as successful methods were found they were put into practice. The experiments here reported show the development of the project.

EXPERIMENTS IN 1925

The first experiments were undertaken in 1925, to ascertain whether transplanting could be carried on under Utah conditions. The beets used for transplanting purposes were seedlings from a commercial field, which had been planted April 15. These were dug up and reset by hand on May 13 in rows adjacent to the undisturbed field-run beets of the same planting.[4] As part of the same test an

[3] Goss, A., and Holt, A. M. NEW MEXICO SUGAR BEETS—1898. N. Mex. Agr. Expt. Sta. Bul. 29 : 194. 1899.
Pritchard, F. J., and Longley, L. E. EXPERIMENTS IN TRANSPLANTING SUGAR BEETS. Jour. Amer. Soc. Agron. 8 : 106–110, illus. 1916.

[4] For comparative purposes alternate arrangement of transplanted plots and check plots was used throughout all experiments presented in this circular.

equal number of plots were planted on May 13 to determine the harvest performance of such late-planted beets as compared with the original commercial seeding and the transplanted beets. In all, 168 plots were used. (Table 1.) It will be seen that the transplanted and late-planted beets did not equal the plots of early standard planting in number of beets per acre, tonnage yield, or in sugar production per acre. The test gave valuable suggestions for future work, indicating the necessity of larger plants for transplanting.

TABLE 1.—*Results from a commercial seeding of sugar beets compared with results from transplanted plants from seeded rows and from late-planted seed, at Salt Lake City, Utah, 1925*

[Seeding April 15, transplanting and late planting May 13]

Plot treatment	Plots	Beets harvested [1]	Yield of beets [1]	Sucrose content	Gross sugar [1]
	Number	*Number*	*Tons*	*Per cent*	*Pounds*
Check (field seeded Apr. 15)	42	21,674	21.38	14.15	6,051
Transplanted (May 13)	42	15,750	17.48	14.75	5,157
Check (field seeded Apr. 15)	42	20,326	[2] 18.86	15.85	5,979
Seed planted at time of transplanting (May 13)	42	16,878	[2] 17.56	15.59	5,475

[1] Calculated to acre basis.
[2] By Student's method significant odds were found, showing that the differences in the tonnage yield between the seeded and the transplanted plots are not due to chance alone.

Another test was conducted on the effect of trimming the leaves of sugar beets at time of transplanting. In this experiment plants of three different ages were used. These were grown in field, cold-frame, and greenhouse, respectively, and were compared with a check series of rows of medium-early, normally planted sugar beets. In another series the same kind of plants were used for transplanting, but approximately half of the leaf area was trimmed off before setting. These plants were carefully set by hand, and each plant was watered at time of setting with 1 pint of water. No irrigation was applied until six weeks later. Each plot consisted of four rows 25 feet long. The results of these tests are shown in Table 2.

TABLE 2.—*Comparison of results from a normal, medium-early planted crop of sugar beets with results obtained from transplanted beets which were (1) trimmed to approximately one-half foliage area at time of planting and (2) left untrimmed, at Salt Lake City, Utah, 1925*

Plot	Source of transplants	Treatment of transplants	Stage of development (number of leaves)	Beets harvested [1]	Yield of beets [1]	Sucrose in beets	Gross sugar [1]
				Number	*Tons*	*Per cent*	*Pounds*
Check (field seeded) [2]			6–8	20,160	20.10	18.1	7,276
Transplanted [3]	Field	Trimmed	6–8	25,200	11.66	19.1	4,454
Do.[3]	do	Not trimmed	6–8	27,120	13.38	17.5	4,683
Do.[3]	Coldframe	Trimmed	10–12	17,280	15.07	18.0	5,425
Do.[3]	do	Not trimmed	10–12	22,200	21.91	17.5	7,669
Do.[3]	Greenhouse	Trimmed	12–14	20,540	18.20	18.9	6,880
Do.[3]	do	Not trimmed	12–14	20,640	25.88	17.8	9,213

[1] Calculated to acre basis.
[2] The field was planted Apr. 15.
[3] All transplanting was done May 25.

The smaller number of harvested beets per acre in many of the transplanted plots as compared with the check (Table 1) is in part due to the greater number of beets surviving in the checks and is also to be attributed to the fact that many of the transplanted beets were below commercial size at harvest time and were not counted. With other crops it has been found that transplanting produces a setback to the growth of the plants. These data indicate that transplanting directly from the seeded rows is not capable of producing profitable yields of sugar beets in comparison with either early seeding or timely replanting. The principal objection to replanting in this area is the lack of moisture, which causes a delayed germination of the seed. Observations on the comparative cost of the transplanting and replanting further substantiate the conclusion drawn from the previous experience, that it is better to replant sugar-beet fields properly where the stand is poor than to try to patch up the poor stand by transplanting in the vacant spots with plants taken from other portions of the field.

The data shown in Table 2 indicate a sharp reduction in both tonnage yield and sugar per acre as a result of partial trimming of leaves. Seemingly, these reductions are greatest when large plants are used for sets. In the two plots, trimmed and untrimmed, in which field-grown plants were used, the yields of sugar per acre do not differ greatly. There is, however, greater tonnage yield in both the untrimmed coldframe and the untrimmed greenhouse grown plants than in the comparable trimmed plants. These results are in accord with field experience when either webworm attack or hail defoliates the plants and causes a setback in the growth. Such defoliations usually result in tonnage losses.

EXPERIMENTS IN 1927

The 1925 tests indicated that while satisfactory yields of sugar beets could probably be obtained by transplanting, there was so much labor involved in hand setting the plants that it was extremely improbable that such a method would be practical. In 1927 a plant-setting machine was obtained and the work renewed. This machine was built by the manufacturer as a horse-drawn outfit, and in the first attempts to set plants, with inexperienced operators, it was found that the horses could not be driven slowly enough to permit the operators to place more than 10,000 plants per acre. At harvest the transplanted plots had a stand of 7,700 beets and a yield of 14.1 tons per acre. As compared with this, the check plots of sugar beets grown in accordance with standard practices had a stand of 25,000 beets and a yield of 19.8 tons per acre. (Table 3.)

TABLE 3.—*Comparison of results from transplanted plots with those obtained from plots grown by standard methods from seed planted in a field and later thinned, at Salt Lake City, Utah, 1927*

Treatment of plot	Beets harvested [1]	Yield of beets [1]	Sucrose in beets	Coefficient of apparent purity of juice	Gross sugar [1]
Team-drawn transplanter:	*Number*	*Tons*	*Per cent*		*Pounds*
Check plot (field seeded Apr. 20)	25,000	19.8	17.6	84.3	6,970
Transplanted plot (coldframe plants set Apr. 29)	7,700	14.1	17.7	83.2	4,991
Tractor-drawn transplanter:					
Check plot (field seeded May 5)	23,500	15.9	16.6	83.1	5,279
Transplanted plot (coldframe plants set May 5)	18,600	19.3	17.0	81.3	6,562

[1] Calculated to acre basis.

The above-mentioned plant-setting machine, after certain improvements had been made, was attached to a tractor, and four plots were transplanted. From these plots 18,600 beets were harvested, whereas the check plots produced 23,500 beets per acre. (Table 3.) The transplanted plots produced 19.3 tons of beets, in contrast to a yield of 15.9 tons per acre from the check plots. These check plots were planted on the same day that the transplanting was done, and in each case all plots were irrigated at once. The transplants had had some water applied directly to the roots at the time of transplanting. This test is probably not a critical comparison of transplanting with the normal method of sugar-beet growing, since the time of seeding in 1927 was delayed about three weeks beyond the optimum time of planting, and transplanting was done at an excellent time for this operation. Past experience has shown that delay as great as this in seeding lowers the yield considerably. The results of the 1927

FIGURE 1.—Sugar beets growing under curly-top conditions at Magna, Utah: A, Transplanted beets showing little injury to foliage by curly top; B, the adjacent check plot (grown from field-sown seed), foliage reduced by curly top. (Photographed September 1, 1928)

plots can best be interpreted by the statement that by transplanting by a tractor-drawn machine sufficient plants were set to the acre to give a good commercial yield. The introduction of machine setting and the modifications to suit the conditions opened the way for extensive plantings the next season.

EXPERIMENTS IN 1928

In continuation of the work of 1925 and 1927, a series of transplanting experiments were conducted in Utah and Idaho in 1928. In Utah, coldframe and greenhouse grown plants were set by machine, May 5, for comparison with normal beet production of check plots seeded a week earlier. Each plot contained 15 rows 300 feet long. These plots were damaged by curly-top disease, which was prevalent in Utah that year. On July 2, in counting beets with curly-top symptoms on leaves, it was found that the transplanted plots showed but 18 per cent visibly diseased beets, whereas the check plots showed 33 per cent. (Fig. 1.) At harvest time all of the beets

in both series showed signs of curly top. The curly-top counts were made by careful examination of all the leaves of several hundred plants in representative areas in the plots. (Table 4.) These percentages represent the natural invasion of the leaf hopper (*Eutettix tenellus* Baker) and indicate more or less escape of the transplanted beets from the severer forms of curly-top injury.

TABLE 4.—*Comparison of results from transplanted plots with those from check plots planted following standard practice, at Magna, Utah, 1928*

Planting method	Beets harvested [1]	Yield of beets [1] [2]	Sucrose in beets	Coefficient of apparent purity of juice	Gross sugar [1]	Curly top visible in beets July 2
	Number	*Tons*	*Per cent*		*Pounds*	*Per cent*
Check (field seeded Apr. 28)	22,000	17.7	16.7	85.7	5,912	33
Coldframe plants (transplanted May 5)	14,900	19.1	16.5	83.9	6,303	18
Greenhouse plants (transplanted May 5)	19,600	25.6	16.1	82.0	8,243	18

[1] Calculated to acre basis.
[2] Curly top was a factor affecting yields.

Another comparative test, consisting of plots four rows wide and one-tenth acre in size, was conducted at Twin Falls, Idaho. In this test the plants were hand planted. The greenhouse plants had 10 to 12 leaves when transplanted on May 11. The check plots planted April 21 had two to four leaves on May 11. The seeded plot was thinned in accordance with standard practice, and an excellent stand resulted. A corresponding number of plants (computed on an acre basis) were set in the transplanted plot. (Table 5.)

TABLE 5.—*Comparison of results from transplanted plots with those from check plots planted following the standard practice, at Twin Falls, Idaho, 1928*

Planting method	Beets harvested [1]	Yield of beets [1] [2]	Weight per beet	Sucrose in beets	Coefficient of apparent purity of juice	Gross sugar [1]	Curly top visible in beets June 28
	Number	*Tons*	*Pounds*	*Per cent*		*Pounds*	*Per cent*
Check (field seeded Apr. 21)	15,300	5.9	0.77	18.0	89.1	2,124	45
Greenhouse plants (transplanted May 11)	19,600	11.8	1.21	18.4	87.7	4,342	15

[1] Calculated to acre basis. [2] Curly top was a factor affecting yields.

In the Utah plots, in spite of the poorer stands of transplanted beets caused by mechanical difficulties with the transplanting machine, the check plot was decidedly inferior in yield to the transplanted plots, growing 1.4 tons less per acre than the plot set with plants grown in the coldframe and 7.9 tons less than the plot set with plants grown in the greenhouse. However, the yield of 17.7 tons from the check plot indicates that the damage from curly top was not very severe.

In the case of the Idaho experiments, curly-top damage was severe, as is plainly evident from the harvest data. The severe reduction in stand, based on the harvest-time count, as compared with the stand count made after thinning, is attributable to the curly-top

disease. On June 28, 45 per cent of the beets in the check plots were visibly affected with curly top, as compared with 15 per cent in the transplanted plots. The infection increased as the season advanced, and at harvest all the beets in both series were diseased. Neither plot produced a profitable yield, but the transplanted plot produced nearly double the yield of the check plot. This may be due to the fact that diseased beets seldom more than double in weight after becoming visibly diseased by curly top. The observation that transplanted beets do not develop symptoms of curly top so rapidly as seeded commercial beets may be due to the fact that the transplants are older and larger in size at the time of transplanting and are less sensitive to curly top. Further, the insects that transmit curly top apparently prefer the environment furnished by the sparse vegetation of the smaller beets and may have avoided the larger beets. Attention is called to the significance of this finding in its relation to curly-top control.

EXPERIMENTS IN 1929

In the 1929 transplanting tests, sugar-beet plants grown in local greenhouses, coldframes, and in open-field plantings at St. George, Utah,[5] were used for setting. Four fields in the Utah and Idaho areas were selected for the transplanting work, each series being sufficiently replicated to allow of statistical interpretation of results.

The largest transplanting test was made at Magna, Utah, where twelve 4-row plots, in which the rows were 300 feet long, were grown. Twelve plots of the same size, in which the sugar beets were grown in the standard manner, were included in this test as checks. The Magna field was spring plowed, and the check plots were seeded on May 7. This land was dry at the time of planting, and the seed germinated unevenly and slowly. To complete germination the rows were furrowed and irrigated at the time the plants were set in the adjacent plots. Transplanting was done by a motor-driven transplanting machine. Mechanical difficulties with the machine caused the transplanting to extend from May 23 to June 2. It was possible to obtain water for irrigation only two days a week, and none of the transplanted plots were irrigated until June 1 and 2. In the case of 6 of the 12 transplanted plots, plants that were set on May 23 were watered with a small quantity of water applied to each root at time of planting and were very dry until irrigated. It is evident that in this field neither the transplanted nor the check plots had satisfactory conditions for the production of a maximum crop. Both the transplanted seedlings and the plants in the checkrows were damaged by the delayed planting, adverse weather, and the dry condition of the soil.

At Sandy, Utah, 24 single rows, each 65 feet long, were set May 11 with field-grown plants from St. George, Utah. These had been planted in an open field on February 10 and were dug May 6. The check plots were planted May 3 under standard procedure for sugar-beet growing. At the time of transplanting, the check plots were in the cotyledon stage, and the transplanted beets had 8 to 10 leaves. The transplanting in this experiment was done with a horse-drawn machine which did not permit of placing the beets at regular inter-

[5] The season at St. George, Utah, is several weeks in advance of the season in northern Utah, permitting open-field planting in early February.

vals of 12 inches, there being an alternation of 12-inch and 24-inch spaces between plants.

The test at Logan, Utah, was small and consisted of seven single rows, each 75 feet in length. The plants used as sets were greenhouse grown and had 10 to 12 leaves when transplanted May 14. The transplanting was done by hand. The checkrows in which beets were grown under standard procedure were planted the same day. The planting of this field had been delayed by the unusual weather conditions of 1929 and may be considered as a late planting for the area. This test gives indications of the value of transplanting for "late lands." The plants were very carefully set, each root being placed in an upright position in the soil, the soil made firm around it, and then watered. Irrigation was applied to the entire field two days later. (Fig. 2.)

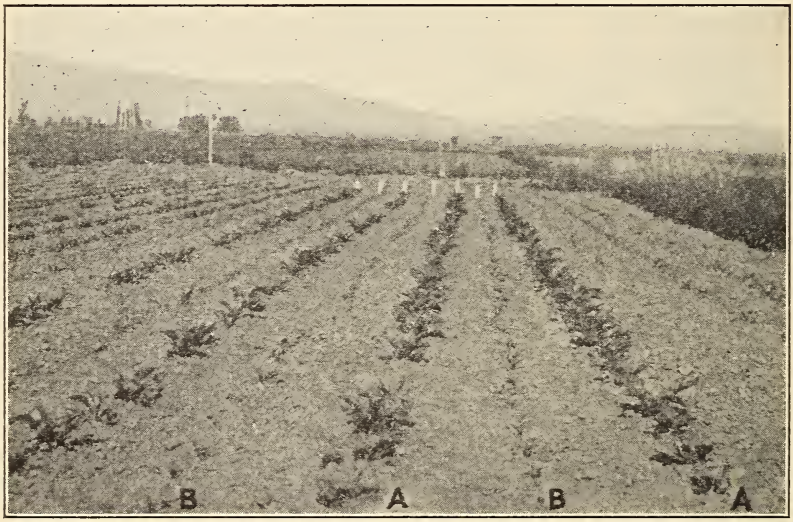

FIGURE 2.—Rows of (A) transplanted sugar beets with (B) checkrows of normally planted sugar beets, illustrating gain in size of plant obtainable by use of large transplants. Photograph taken shortly after thinning the checkrows. (Logan, Utah, 1929)

The test at Twin Falls, Idaho, consisted of 9 plots of transplanted sugar beets and 9 check plots, the 2 types of planting being alternated throughout the field. Each plot was 150 feet long and consisted of four rows. The transplanted beets were grown at St. George, Utah, and had 8 to 10 leaves each when set by hand on May 9. The check plots in which standard practice was followed were planted the same day on which the transplanting was done, and irrigation water was immediately applied to moisten the seed and to protect the plants from excessive drying. Ten plots of commercial beets standing adjacent in which the seed was planted two weeks earlier produced an average of 15.5 tons of beets per acre, in comparison with a yield of 15.9 tons for the later seeding used as checks. This indicates that the yield of the check plots was approximately normal for the field for the year 1929. (Table 6.)

TABLE 6.—*Comparative yields of sugar beets from transplanted and check plots grown in Utah and Idaho in 1929*

[Results given as averages for each location]

Location and treatment of plot	Plots	Beets harvested [1]	Yield of beets [1]	Sucrose in beets	Coefficient of apparent purity of juice	Gross sugar [1, 2]
Magna, Utah:	*Number*	*Number*	*Tons*	*Per cent*		*Pounds*
Transplanted	12	15,821±1,710	17.17±0.52	16.42±0.40	85.0±0.66	5,633±208
Seeded check	12	13,479± 790	12.17± .87	17.05± .22	86.2± .66	4,081±241
Sandy, Utah:						
Transplanted	24	15,532± 247	19.64± .29	16.77± .09	86.1± .29	6,577±107
Seeded check	24	22,132± 302	17.58± .33	17.32± .12	87.5± .33	6,099± 96
Twin Falls, Idaho:						
Transplanted	9	26,267± 534	21.80± .41	18.70± .12	90.7± .82	7,712±235
Seeded check	9	31,415± 790	15.90± .45	18.80± .16	89.7±1.02	5,969±173
Logan, Utah:						
Transplanted	7	18,148± 553	19.05± .66	17.50± .10	87.7± .22	6,822±181
Seeded check	7	19,506± 713	7.79± .44	17.90± .21	87.9± .68	2,575±143
Average: [3]						
Transplanted	52	17,809± 419	19.42± .24	17.1± .12	86.8± .30	6,579±102
Seeded check	52	21,388± 594	14.73± .40	17.6± .10	87.6± .28	5,239±139

[1] Calculated to acre basis.
[2] Weighted to take into account number of plots involved at various locations.
[3] The gross sugar per acre was obtained by multiplying the yield per acre in pounds by the per cent of sucrose in beets for each plot and obtaining the average yield of plots of all series. This figure varies slightly from the product obtained by the multiplication of the average yield by the average sucrose per cent shown in the above table.

The average stand (computed on an acre basis for beets actually harvested) of the transplanted plots was 3,579 less than the corresponding number for the seeded check plots (Table 6, column 3). It will be noted that in three of the four experiments this condition held, whereas in the fourth the relations were reversed. In the field at Magna, Utah, curly top was present and did considerable damage to the check plots, making many of them unmarketable at harvest. Considering the average figures, it will be seen that, in spite of the disparity in stand as shown by the average figures, the average gain of the transplanted beets over the checks was 4.69 tons per acre, with odds 10,000 to 1 that a gain as large as this was not due to chance alone. (Mean square error of difference test.)[6]

The comparative quality of the transplanted beets and the checks are shown in columns 5 and 6 of Table 6. These figures were obtained from 52 random samples of 5 or 10 beets from each transplanted plot and compared with an equal number of similar samples from check plots. The average of these findings shows a sucrose content 0.5 per cent lower and a coefficient of apparent purity 0.8 smaller in the transplanted plots than in the check plots. The difference in sucrose percentage by the mean square error of difference method [7] shows odds 26 to 1 that it is not due to chance alone. Such odds are on the border line of being considered significant. The difference in coefficients of purity, similarly considered, shows odds of only 4 to 1 that such a difference was not due to chance alone, and such odds are not significant. The quality of the beets, therefore,

[6] PEARL, R. INTRODUCTION TO MEDICAL BIOMETRY AND STATISTICS. Table 40, p. 218. Philadelphia and London. 1923.
[7] PEARL, R. Op. cit.

produced in the transplanted and the check plots was approximately the same.

Since the difference in sucrose percentage was small, the gross sugar per acre of the transplanted plots was not markedly affected by this small difference in quality, and figures given reflect the yield differences. The yield of gross sugar per acre was 5,239 pounds for the check plots, and 6,579 pounds for the transplanted plots, a difference of 1,340 pounds in favor of transplanting.

The shape of root produced from transplanted sugar-beet sets deserves comment. The general experience in all of the tests from 1925 to 1929, inclusive, was that transplanted beets produced more short, off-type, and round beets than were produced from the checks or are to be found in commercially grown sugar beets. (Fig. 3.) Throughout the years of test a search was made for roots of perfect shape in the transplanted beets, but none were found. In 1929 a special effort was made to set 500 sugar beets with the roots of the transplants straight and plumb. From these plants not one perfectly

FIGURE 3.—Yields from adjacent plots of (A) field-seeded and (B) transplanted sugar beets. The transplanted beets are larger and have taproots more branched than those of field-seeded beets. (Magna, Utah, October, 1929)

tapering root was harvested. As a result of this work, no method has thus far been found that will produce transplanted beets with the tapering shape of root.

DISCUSSION

PRODUCTION OF YOUNG PLANTS FOR SETTING

Methods of producing sugar-beet plants for transplanting purposes, listed in order of importance as determined by the results of these experiments, are as follows: Greenhouse, hotbed, coldframe, and local open-field planting. The least costly method of growing plants was by the local open-field method. This, however, offers very little opportunity for increasing the length of the growing season. Some plants were grown experimentally in open fields in warmer climates and transported for transplanting. A transportation problem is involved both as to cost of transportation and as to proper preparation of plants for shipment. A problem still to be determined is whether plants can be more efficiently and economically produced by individual growers or whether they can be more

advantageously purchased from organizations engaged in commercial plant growing. Where plants were produced in the greenhouse, hotbed, or coldframe, advantage was taken of a well-conditioned soil as to texture, fertility, and good depth, so as to insure a straight taproot growth. Where flats were used, at least 6 to 8 inches depth of soil was necessary for best results.

Great care was exercised in the treatment and planting of the seed so as to insure strong, healthy plants. For seed treatment, organic-mercury compounds were used. The seed was planted in well-prepared beds which were allowed to warm up prior to planting, and the seed was planted 1 inch deep in rows about 3 inches apart. Under average conditions 100 plants were grown on 1 square foot of bed space, which makes possible the setting of 1 acre from the plants grown in 260 square feet of space. A pound of seed is necessary to plant this area properly, no thinning of the plants in the bed being necessary. Planting was done early enough to produce plants having 8 to 14 leaves at the time of transplanting. It was found from general practice that smaller plants were of little value and hard to set in the fields, while larger plants were injured too severely by their removal from the beds and by the subsequent pruning of leaves, necessary to fit them for proper transplanting. Generally, where the transplanting was intended to be made around April 20 to May 10, the seed was planted from February 15 to March 5. Ordinary precautions were taken in properly hardening the plants several days prior to transplanting. The coverings were entirely removed and the plants exposed to normal temperatures. Where plants were grown in the field instead of under protective covering, the plantings were made in rows 6 inches apart, with each fourth row omitted, to allow for ample furrow irrigation.

DIGGING AND HANDLING

Best results were obtained when the beds were heavily soaked with water a few hours prior to being dug. The plants were then carefully dug. No attempts were made to set plants with soil adhering to the roots, as it was found that plants were hard to handle in such a condition. If the top 5 inches of the beet root was uninjured in the course of removal from the bed, it was believed that such a plant was usable. It was thought that to attempt to save more of the root would make planting more difficult and not greatly benefit the yield. Sorting of plants was carefully practiced, the small and otherwise inferior plants being discarded. The plants were then placed in bunches of approximately 50 each, with the roots straight and all in one direction. The plants were kept in good condition by wrapping each group with a sheet of oiled or common wrapping paper. These bunches were carefully placed in boxes so that the tops were uppermost and the roots straight downward. Injury from drying was avoided by frequent watering and careful packing. Heating of plants was prevented by keeping them in a cold place. When delays in transplanting occurred, or when plants were prepared for shipping, it was found that they could be kept in cold storage at 32° F. constant temperature for a period of 10 days without great injury. It should be added, however, that this practice should be used only in an emergency or when shipping the plants.

SETTING THE PLANTS

In these experiments an effort was made to set one plant to each 12 inches of row space in rows 20 inches apart, so as to conform to the standard spacing for commercial fields. However, as has been noted, in some instances it was impossible to operate the transplanting machinery so as to set the plants as close as this. The plants grew best when they were set with straight roots firmly packed in the soil and the crown of the beet held even with or somewhat below the surface of the soil. It was definitely established that it is better to place the crown 1 inch below the surface of the soil than to have a part of it exposed. Exposed beets tend to dry out and often die before the plants become established. On the other hand, the deep-set crowns dried out less and were seldom smothered by a small quantity of soil covering the crown. Where commercial fertilizer was used, care was taken not to place it in close contact with the roots. Excessive puddling of the soil was likewise found to be detrimental. With respect to the size of plant, one that had from 8 to 14 leaves and a root ranging from one-eighth to three-eighths of an inch in diameter was found to possess sufficient vitality to become properly established under favorable conditions.

Machine setting of plants compared very favorably with hand setting when a good type of machine was used. The better types of machines were capable of setting the plants firmly, straight, and at even distances. They were supplied with attachments for watering each plant. Hand setting was a very slow, tedious method and was not used except in an experimental manner. Approximately 100 hours of man labor were required to hand set 1 acre of sugar beets. Machine setting was from three to seven times more rapid. The present machines in some instances can not handle plants with more than 14 leaves unless the leaves are trimmed. These experiments were not conducted on a sufficiently large scale to give accurate figures as to the comparative cost of the various operations. The machines used did better work than that obtained from hand setting, but the types with which the writer is familiar are as yet not perfected to the extent that they could be relied upon for use on a large commercial scale.

OBSERVATIONS ON GROWTH OF TRANSPLANTED SUGAR BEETS

Very few plants died when properly set. The mortality losses were usually less than 5 per cent of the total. In many of the experiments reported the smaller number of beets at harvest time on the transplanted plots was primarily due to failure to set a sufficient number of plants. These losses will be largely avoidable as the technic of handling the sets and the machinery are improved. During the first day or two the plants wilted slightly and in some instances lost their original leaves. Plants transplanted earlier in the season suffered less from adverse temperature and humidity effects than those planted later when hot and dry weather ensued. Secondary roots developed shortly after transplanting, and new leaves began to appear 3 days after transplanting. The growth was slow for a period of 6 to 10 days or until the plants became established, after which a rapid growth took place.

As has been indicated, the roots of the transplanted beets were shorter, more branched, and somewhat larger in circumference than

comparable commercial beets. These roots were more difficult to top than those from the commercial plantings. The sugar yield per acre was decidedly in favor of the transplanted beets.

Bolting or seed-stalk production as a result of the transplanting operation was not found to be a factor in the transplanted beets in the areas where these tests were made. Less than 1 per cent of the transplanted beets produced seed stalks. In comparison, however, it should also be noted that in the commercial fields in these areas seed stalks are rarely to be seen.

COSTS INVOLVED IN TRANSPLANTING

In the Utah and Idaho areas approximately 18 pounds of sugar-beet seed is used to plant an acre of sugar beets grown in the standard manner. The seed required to furnish enough sets to transplant an acre is only 10 to 20 per cent of this amount, because all plants of suitable size produced in the seed bed are used. A saving is effected in this way, since the ordinary crop requires 15 to 20 pounds of seed per acre, valued at approximately 15 cents a pound. The saving in seed requirement can be placed at approximately $2 an acre when the transplanting method is used.

The cost of preparing the land is no greater for transplanted beets than for the commercially seeded beets. The work can be done somewhat later in the season and offers some advantage in permitting more time for manuring and preparing the land.

The cost of growing the plants varies with the methods used in their production. The present cost of sets for commercial plantings of onions and tomatoes in an area may be taken as an indication of the probable cost of sugar-beet plants. It is likely that tomato plants cost somewhat more and onion plants slightly less to grow than sugar-beet plants. In this area tomato plants cost from $2 to $4 a thousand plants, and onion plants cost from 80 cents to $1 a thousand. The cost of sugar-beet plants for each acre set, figured on such a basis, would range from $21 to $100. If a large commercial demand for sugar beets developed it should be possible to reduce this cost considerably, perhaps $10 to $20 an acre.

The setting of the plants in the field at present is very expensive. Hand planting of sugar beets costs approximately $40 an acre. Machine setting is less expensive. One machine was used for which the claim was made that it would set the plants at a cost of approximately $10 an acre. It was claimed that this machine with 2 men could set 40,000 plants in 8 hours. This was assuming that the plants and water would be supplied and that the machine would be operated constantly. The perfecting of plant-setting machines may reduce considerably the cost of setting the plants. It is not safe to estimate the cost per acre for machine setting at this time.

It is not necessary to thin the sugar beets when they are transplanted. This saving amounts to $7 to $10 an acre.

The field is tilled and all weeds destroyed in the preparation of the soil for transplanting, and this leaves the sugar-beet row more free from weeds than does the standard operations of thinning and hoeing commercial beets. The cost of hoeing is probably reduced from $1 to $2 an acre.

The plants are of thinning size when transplanted, whereas the seeded field is normally cultivated once or twice before the plants are of this size. This item would probably reduce the cost of cultivation from $1 to $2 an acre.

The cost of irrigation for transplanted beets is the same as or slightly greater than that for seeded fields. The irrigation that is applied at the time of setting the plants is an extra cost in some areas. In areas where irrigation is necessary to germinate the seed, this should not be counted as an additional cost.

From the experience of these tests extending from 1925 to 1929, and especially in view of the 1929 experience, it is believed that increased yields can be obtained by transplanting sugar beets of proper size. With the savings enumerated it is evident that an increase in yield of at least 2 tons per acre, over what would be obtained from standard practice would be required to meet the additional costs involved. The indications are that gains far in excess of this may be made. The United States Department of Agriculture is not advocating the supplanting of present practices in beet growing by the use of transplants, but it is calling attention to the possibilities of the method and suggesting the desirability of further tests.

SUMMARY

Results obtained from four years of work indicate that sugar-beet yields can probably be increased from 1 to 8 tons an acre by proper transplanting methods. In these tests most of the beets were transplanted when they had from 8 to 14 leaves. The yields were compared with those from adjoining check plots which had been planted in the standard manner.

These tests show that the sugar-beet plants used as sets should be at least 8 weeks and not more than 12 weeks old at the time of transplanting and should have from 12 to 14 leaves. Proper precaution must be taken in setting out the plants. Best results were obtained when the crown of the beet was set even with or below the soil surface and when water was applied directly to the root in the transplanting process.

The beet roots obtained by transplants in these tests were short, round, and more branched than those obtained under the commercial method. However, this shape was not associated with a serious decline in quality of the beet.

Infection of sugar beets by curly top occurred in the 1928 experiments, and the disease appeared to be less detrimental to the transplanted sugar beets than to the field-sown checks. Attention is called to the significance of this finding in relation to curly-top control.

Sugar production per acre was generally in favor of the transplanted beets for the four years of experiments herein presented, and strongly so for the large-scale tests of 1929, which are believed to be a safe index of advantages derived from transplanting sugar beets. The Department of Agriculture is not recommending transplanting as a method to supplant present practices, but is calling attention to the possibilities of the method.

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